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Title

Further Observations on the Starfish and Soviet Artificial Radiation Belts

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(see over)

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ABSTRACT

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A sketch is given of the time decay of the Starfish radiation belt over a one year period using data from SUI/ONR satellites Injun I and Injun III. As an example, the apparent mean lifetime of ~ 2 MeV electrons for the period $400 \leq \Delta t \leq 1200$ hours after the burst for $L = 1.185$ is about 33 days, more-or-less independent of B over the range 0.195 to 0.220 gauss. For $L \gtrsim 1.5$ the observed decay is well explained by the quiescent scattering and energy loss in the atmosphere as calculated in detail by Walt. The peak intensity of electrons in the Starfish belt was initially $J_o \sim 1.4 \times 10^9$ $(cm^2\ sec)^{-1}$ at $L = 1.18$ on the equator. By June-July 1963, one year later, it was $J_o \leq 1.5 \times 10^8$ $(cm^2\ sec)^{-1}$ at $L = 1.35$ on the equator. The mean lifetime of ~ 2 MeV electrons at the most durable portion of the Starfish belt ($L \sim 1.35$) is about 16 months (or about two orders of magnitude less than the estimate of Hess et al. in September 1962). About 10% of initially injected electrons (dominantly the higher energy ones) remained trapped at the end of one year. The total number initially injected was $\sim 1.3 \times 10^{25}$, about 3% of the total number of fission-decay electrons available from the Starfish burst.

13057

A preliminary report on the time history of two of the three artificial radiation belts produced by Soviet high altitude atomic bursts in October-November 1962 is given. The data are from S.U.I. equipment in the N.A.S.A. satellite Explorer XIV (courtesy of L. A. Frank). The mean lifetime of electrons of $E > 250$ keV was of the order of 25 days for $2.4 \leq L \leq 3.6$. At $L \gtrsim 3.6$ there were marked natural fluctuations.

Thus, in agreement with previous evidence, it is confirmed that trapping life-times increase rapidly with increasing altitude (due to diminishing atmospheric density), have a maximum of the order of a year at $L \sim 1.4$, then decline to values of the order of days to weeks at $L \gtrsim 2.0$ (due to magnetic and electromagnetic perturbations).

It is urged that an official government report be prepared, summarizing current evidence, in order to correct the excessively high estimates of the injection efficiency, physical extent, and lifetime predictions which were contained in early, widely distributed government documents in the fall of 1962 and to provide satellite engineers with realistic design specifications.

It is noted that the 1962-63 epoch is one of near-minimum solar activity and that considerably reduced lifetimes may be expected during 1967-68-69 due to increase of atmospheric density at high altitudes and to enhanced geomagnetic perturbations.

AUTHOR

1. Introduction

There are reported herein some further results on the long-term history of the Starfish radiation belt which have been obtained since our report to the Symposium of the Defense Atomic Support Agency on 15, 16 April 1963 [Van Allen, 1963a]. The bases for extension of the earlier work are as follows:

(a) The Injun I data for the one year period preceding the Starfish event and for the two month period following the event have been reduced again and matched against B and L values computed with the improved McIlwain program which employs the Jensen-Cain coefficients for the epoch 1960. Although this work has not yet been completed, it appears that the earlier work on the spatial distribution and time decay of the intensity of energetic electrons will not be changed in any important way, though the scatter of the experimental points is reduced somewhat.

(b) Dr. B. J. Farmer of the Ling-Temco-Vought Research Center in Dallas has run a comprehensive set of experimental calibrations of our flight-spare, shielded Geiger tube (SpB) using electron beams from the LTV Van de Graaff up to 2.4 MeV. These results will be reported later in full. They give a very good confirmation of the form of earlier, calculated efficiency curves and show that the previously used absolute efficiency of the SpB detector [Van Allen, 1963a] was not in error by more than 50%.

(c) We have continued to follow the time decay of intensity of the Starfish electrons with Injun III, which carries an SpB detector substantially identical to the one in Injun I, as well as a variety of other detectors which detect the electrons directly. A large body of Injun III data is available for the period 13 December 1962 through October 1963. The initial parameters of the orbit of Injun III were as follows:

Inclination of Orbit	70.4°
Period	116.3 minutes
Altitude of Perigee	230 km
Altitude of Apogee	2800 km.

By virtue of the fact that the apogee of Injun III's orbit is considerably higher than that of Injun I, much improved coverage of the outer portion of the Starfish belt has been achieved (up to L = 1.5 on the equator). Results from the SpB detector of Injun III are reported herein. A much fuller knowledge of the detailed composition and long-term history of the Starfish belt will be obtained when the data from the other detectors have been reduced.

In addition to the above, there is given herein a series of curves on the time decay of the first two of the three Soviet artificial radiation belts which were produced in October-November 1962. These results were obtained by S.U.I. equipment in Explorer XIV, launched on 2 October 1962. Both pre-burst and post-burst data are given for the period October 1962 through February 1963, using a detector which measured the electrons directly with an open-ended, thin-window Geiger tube. Initial parameters of the orbit of Explorer XIV were:

Inclination of Orbit	33.0°
Period	2185 minutes
Altitude of Perigee	281 km
Altitude of Apogee	98,533 km.

2. Brief Review of Injun I Results

Among the various detectors in the S.U.I./O.N.R. satellite Injun I, the heavily shielded Geiger tube SpB has proved to be the most generally useful for determining the spatial structure and time decay of the intensities of the Starfish, though auxiliary information has been obtained with several of the other detectors. Two previous papers on Injun I results have been published [O'Brien, Laughlin, and Van Allen, 1962] [Van Allen, Frank, and O'Brien, 1963] and two S.U.I. preprints have been distributed [Van Allen, 1963a; Van Allen, 1963b] and included in D.A.S.A. documents.

The more recent study of Injun I data (cf. Introduction) has given no reason for substantial modification of earlier results. The characteristic of SpB for the detection of electrons (Figure 1) and the initial configuration of the Starfish belt (left hand portion of Figure 2) are reproduced from the previous paper, which should be consulted for further detail. There were estimated to have been a total of

$$1.3 \times 10^{25}$$

electrons present in the Starfish radiation belt at $\Delta t \sim 10$ hours. The directly determined in-flight efficiency of

$J_o/R = 10^5$ cm^2 was in good agreement with that expected by Figure 1 for a Carter-Reines-Wagner-Wyman electron spectrum.

One of the final time-decay curves from Injun I data is given in Figure 3. As with the previously reported time decay curves and accompanying discussion [Van Allen, 1963a], it is seen that:

(a) The apparent mean lifetimes (derived from the instantaneous slope of the curves of log (counting rate) vs elapsed time) increased markedly during the first 300 hours, the effect being greater at larger B values (smaller minimum altitude h_{min} values);

(b) After the first 300 hours, the apparent mean lifetimes for a given L value (i.e., for a given magnetic "shell") were approximately independent of B (or of h_{min}).

As shown in an accompanying paper by Martin Walt, the set of curves shown in Figure 3 has received an essentially complete explanation, both qualitatively and quantitatively, in terms of quiescent outscattering and energy loss in the atmosphere. In the theoretical calculations, the best available data on atmospheric density and molecular, atomic, and electronic composition as a function of altitude were used; the trapped particle motion in the real geomagnetic field was treated at a high level of precision; the observed initial distribution

(Figure 4) was taken as the starting point in the calculation; and the energy dependence of the sensitivity of the SpB (Figure 1) was adopted.

The success of Walt's calculations (at $L \lesssim 1.2$) constitutes a most important advance in understanding the physical dynamics of the inner zone.

Extension of this work to higher L shells by Walt and by the writer is in progress using both Injun I and Injun III data. The latter continues the time history to a total Δt of over 14 months with a homogeneous technique.

By Figure 3, the apparent mean lifetime for the period $400 \leq \Delta t \leq 1200$ hours for $1.175 \leq L \leq 1.195$ is about

33 days

more-or-less independent of B over the range $0.195 \leq B \leq 0.220$ gauss. By Figure 1 and the calculated spectral curves of Walt, this value is understood as appropriate to an effective electron energy of about 2.5 MeV. It should be noted that this value is appropriate to a period of low solar activity and of markedly depressed atmospheric density at high altitudes, as discussed in more detail below.

3. Injun III Results

A large body of Injun III observations with an SpB detector nominally identical to that in Injun I is now available for the period 13 December 1962 through October 1963. There is a corresponding body of simultaneous observations with a family of direct, directional detectors. The value of the latter is greatly enhanced by the fact that Injun III is a magnetically oriented satellite so that measurements with direct, directional detectors are made at known angles to local magnetic vector, especially perpendicular to B. A full reduction of the observations will not be available for some months. The present section presents preliminary summaries of the SpB results.

It is difficult to make a thoroughly satisfactory comparison of the absolute efficiencies of the SpB in Injun III with that in Injun I since strictly comparable calibrations were not performed on the respective flight units. They were substantially identical in shielding and employed nominally identical 213 Geiger tubes. In previous work it has been found that these small tubes differ in effective omnidirectionally-averaged cross-section by as much as a factor of two. At high latitudes the counting rate due to galactic cosmic rays of the SpB in Injun III (Dec. 1962 - Jan. - Feb. 1963) was found to be 2.2 times as great as the corresponding rate of the SpB in Injun I (Sept. - Oct. 1961).

On the basis of miscellaneous information on galactic cosmic ray intensity from Pioneer IV, Lunik I, Lunik II, Explorer XII, Explorer XIV, Lunik IV, Mariner II, and Mars I by various American and Soviet experimenters, it appears that the interplanetary cosmic ray intensity increased by about a factor of 2 between March 1959 and late 1962. Most of this increase apparently occurred after February 1961. Thus we tentatively conclude that the effective cross-section of the SpB in Injun III was 1.5 to 2 times as great as that in Injun I for penetrating particles and (hopefully) about the same for bremsstrahlung. In joining together the Injun I and Injun III series of measurements and, perhaps more importantly, in assessing the background subtraction due to natural inner-zone protons, the uncertainty in this factor must be borne in mind.

Due to the slow decay of the Starfish belt over the period $6 \lesssim \Delta t \lesssim 14$ months, intensity contours of very good accuracy can be found by combining all data on the (true) counting rate of the SpB during a two or three month period into a single diagram.

Figure 5 is such a diagram for December 1962 and January and February 1963, and Figure 6, for June and July 1963. The continued shrinkage of the Starfish belt is evident, though it should be noted that by $\Delta t \sim 12$ months the counting-rate contribution of natural protons (cf. Figure 3 of Van Allen, 1963a) is important and, in some regions of B-L space, dominant.

Thus, in Figure 7 is given a preliminary summary of the time history of SpB counting rate vs B within the magnetic shell $1.175 \leq L \leq 1.195$. The decay of the Starfish contribution by a factor of the order of 100 is evident between 9 July 1962 and June 1963. There is an apparent lack of decay between January and April 1963, which is not understood. But one of the immediately striking features of Figure 7 is that for $B > 0.203$ there appears to have been essentially no decay in the counting rate of SpB during a six month period. From this fact and from the form of the counting rate vs B curves it appears that the Starfish contribution has shrunk to a negligible fraction of that due to the natural radiation. If this is indeed so then, even if Injun III rates are divided by a factor as great as 2, the natural inner zone intensity on the $L = 1.185$ shell increased by a factor larger than 2 between early 1961 and mid-1963. Such an increase is plausibly linked to the marked reduction in atmospheric density at high altitudes which has been found by air drag measurements on various satellites during this period and attributed to a diminution of solar heating of the atmosphere [Jacchia, 1963] [King-Hele and Rees, 1963] [Nicolet, 1963] as the general solar activity has declined.

On this line of thought, one can easily estimate a lower limit to the source function for protons of $E > 40$ MeV in the inner zone. Thus, at $L = 1.185$, $B = 0.19$ the omnidirectional intensity of such particles increased by 7×10^2 $(cm^2 \ sec)^{-1}$ within a two year period. If one further assumes no atmospheric losses during this period (in the spirit of obtaining a lower limit) one finds that the source function

$$S \geq \frac{7 \times 10^2}{(6 \times 10^7)\ (0.283)\ (3 \times 10^{10})}$$

or

$$S \geq 1.4 \times 10^{-15}\ (cm^3\ sec)^{-1}\ .$$

Upon comparison with the cosmic-ray neutron albedo yield function ($\sim 2 \times 10^{-14}$ $(cm^3 \ sec)^{-1}$) /Hess, Canfield, and Lingenfelter, 1961/ it is evident that the above possibility is plausible. Further analysis of this aspect of the present results is being done with the object of direct determination of the inner zone source function.

Another view of this same matter and perhaps the best single presentation of the time history of the Starfish belt is shown by the equatorial section of Figure 8. The lower edge of the natural inner zone at $\lambda = 0°$ is seen to have moved to lower altitudes by 115 to 170 km depending on whether one divides the counting rates of the Injun III SpB rates by 2 or by 1 for comparison with those of the Injun I SpB.

The time history of the Starfish belt, as measured by a shielded Geiger tube, is exhibited in simplified form in Figure 8.

(a) The contribution of the Starfish electrons to the counting rate of the SpB at about one year after the burst is negligible compared to that of the natural radiation (i.e., $J_o \lesssim 2 \times 10^7$ $(cm^2 \ sec)^{-1}$ of fission spectrum electron or equivalent) for $L < 1.17$ <u>and</u> for $L \gtrsim 1.6$.

(b) The peak intensity of the Starfish belt has shifted its initial value of $J_o \sim 1.4 \times 10^9$ $(cm^2 \ sec)^{-1}$ at $L = 1.18$ (9-10 July 1962) to $J_o \lesssim 1.5 \times 10^8$ $(cm^2 \ sec)^{-1}$ at $L = 1.35$ (June 1963).

(c) By Figure 8 and Figure 6 it is estimated that the value of the volume integral of the SpB counting rate over the Starfish belt in June 1963 did not exceed 20% of its initial value. In view of the tendency toward more rapid loss of lower energy electrons [Walt, 1963], it is further estimated that about 10% (mostly those of $E > 3$ MeV) of the initially injected Starfish electrons survived one year. It will be recalled in turn [Van Allen, 1963b] that about 3% of the total fission electrons available from the 1.4 megaton burst (5×10^{26}) were present in trapped orbits at $\Delta t \leq 20$ hours.

(d) The mean lifetime of electrons of energy ~ 2 MeV at the most durable part of the Starfish belt (L ~ 1.35) is about 16 months (two orders of magnitude less than the estimates of Hess et al. in September 1962). The mean lifetime is less at both lower and higher values of L.

The data from the full array of Injun III detectors are in process of reduction and will be reported later.

4. Notes on the Soviet Radiation Belts of October-November 1962

Three artificial radiation belts were produced by Soviet high altitude atomic bursts in late 1962. The dates of these bursts have been announced as

22 October ("sub-megaton")
28 October ("sub-megaton")
1 November ("megaton").

Previous observations have been reported by other investigators using NASA's Explorer XV (launched on 27 October 1962) /McIlwain, 1963/ and a D.O.D. satellite /see Bulletin of 44th Annual Meeting of American Geophysical Union, 17-20 April, 1963, Washington, D. C./.

S.U.I. equipment in the NASA satellite Explorer XIV, though not designed for the study of artificial radiation belts /Frank, Van Allen, Whelpley, and Craven, 1963/, has nonetheless provided a valuable survey of the Starfish belt and of the three subsequently-produced Soviet belts. The period of Explorer XIV's operation was from 2 October 1962 to 8 August 1963. Since Explorer XIV was in orbit before any one of the three Soviet bursts occurred, it provides an apparently unique, before-and-after coverage of the particle intensities in the affected regions for all three of these bursts, as did Injun I for Starfish.

Two sets of curves are included in the present report through the courtesy of L. A. Frank of this laboratory. These are given as Figures 9 and 10, which show omnidirectional intensities of particles capable of penetrating 48 mg/cm^2 of aluminum as a function of time from early October 1962 to latter February 1963, for $L \geq 2.4$. The range of geomagnetic latitude of the observations is $15° \leq \lambda \leq 25°$ for $L = 2.4$, 2.6, and 2.8; $10° \leq \lambda \leq 30°$ for $L = 3.2$ and 3.4; and $0° \leq \lambda \leq 20°$ for $L = 3.6$, 4.2, and 4.8. The following features may be noted:

(a) On the magnetic shells $L = 2.4$, 2.6, 2.8, 3.2, 3.4, and 3.6 there was a marked increase in intensity between 21 and 23 October. This increase is attributed to the first of the three Soviet bursts. Such an increase was not seen at $L = 4.2$ and 4.8.

(b) On the magnetic shells $L = 2.4$ and 2.6 a second marked increase, of comparable magnitude to the first, was observed to have occurred between 27 October and 30 October. This increase is attributed to the second of the three Soviet bursts. The increase was not discerned on shells having $L \geq 3.4$.

(c) No increase in intensity due to the third burst was seen for $L \geq 2.4$.

(d) As observed many times before with Explorer IV, Explorer VII, Explorer XII, and Explorer XIV, the natural time fluctuations in the intensity of electrons in the MeV energy range increased markedly with increasing L. For $L \geq 3.6$, natural fluctuations of over a factor-of-ten within times of the order of a day or less are common.

(e) The effects of the first and second Soviet bursts (electrons $E_e \geq 250$ keV) disappeared into the natural background by about 1 January 1963 for L = 2.4, 2.8, and 3.2 and by 15 November for L = 3.6. The apparent mean lifetime was of the order of 25 days for $2.4 \leq L \leq 3.6$. The early disappearance of the artificially injected electrons on the L = 3.6 shell was due to a catastrophic geophysical event, whose influence was also discernible at L = 3.2.

(f) A preliminary estimate of the total inventory of artificially injected electrons from each of the first two Soviet bursts is 1.5×10^{24}.

In Figures 11 and 12 are shown some earlier examples of natural time fluctuations of the intensity of electrons of energy greater than 2 MeV in the outer zone [Forbush, Venkatesan, and McIlwain, 1961] [Forbush, Pizzella, and Venkatesan, 1962]. Similar measurements have also been reported before for the inner zone [Pizzella, McIlwain, and Van Allen, 1962]. Thus, apparent decay lifetimes of the order of weeks for L > 1.9 have been well known for several years.

5. Remarks

(a) Figure 13 provides the basis for noting that 1962-63 is an epoch near the minimum of the current 11-year solar activity cycle. During this period there are markedly reduced losses and perturbations of geomagnetically trapped particles for two principal reasons - markedly reduced atmospheric density at high altitudes and a marked reduction in geomagnetic storm-activity. (King-Hele and Rees [1963] report that the atmospheric density at 400 km diminished by a factor of 5 between 1958 and 1962 while that at 600 km diminished by a factor of 30.) By the same tokens, it is reasonable to expect that particle loss rates will be much greater during the next period of high solar activity (1967-68-69) than during 1962-63. The present writer expects the last observable vestiges of the Starfish belt to disappear by 1969.

(b) Various governmental reports issued in the early fall of 1962 reported ~ 40% injection efficiency of Starfish electrons and quoted anticipated lifetimes of the order of 100 years. The present writer has noted that these early reports are still being used for engineering purposes in various industrial and governmental laboratories. In view of the now overwhelming evidence that these reports gave too high an injection efficiency by about a factor of ten and too long a lifetime by at least a factor of ten, it is clear that many satellite engineers are laboring under quite false and excessive design specifications. The regular scientific literature appears inadequate to correct this situation. Hence, it is urged that D.A.S.A. or another suitable agency should attempt a remedy by issuing a new report summarizing current knowledge and carrying the authority of the federal government.

6. Acknowledgement

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The author is indebted to L. A. Frank for the Explorer XIV summary of paragraph 3 and to D. and B. Venkatesan and S. Burger for assistance with data reduction.

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Walt, M., Analyses of trapped radiation, D.A.S.A. Symposium, November 1963.

CAPTIONS FOR FIGURES

Figure 1. Calculated ratio ($\epsilon = R/J_o$) of the counting rate R of the SpB Geiger tube in Injun I and Injun III due to bremsstrahlung from non-penetrating, monoenergetic electrons of energy E and omnidirectional intensity J_o. dN/dE is the absolute differential spectral intensity of electrons from U fission products (no. of electrons per MeV per fission) according to Carter, Reines, Wagner, and Wyman, Phys. Rev., 113, 280-286, 1959.

Figure 2. Intensity structure of the Starfish radiation belt at two different time epochs. The factor 10^5 is the one applicable to the electron spectrum of Carter et al. (courtesy L. A. Frank).

Figure 3. A final decay curve for the conditions as listed on the diagram.

Figure 4. Initial distribution of SpB counting rate on 9-10 July 1962 (natural background less than 3%) (see Figure 7).

Figure 5. SpB counting rate contours. Background has not been subtracted and is important (see Van Allen, 1963a, and Figure 8).

Figure 6. SpB counting rate contours. Background has not been subtracted and is important (see Van Allen, 1963a, and Figure 8).

Figure 7. A simplified time history for L ~ 1.185.

Figure 8. Equatorial section of the inner zone at several time epochs. The curve marked June/2 has one-half the ordinate values of the curve marked June 1963 Injun III and indicates the lowest level of the counting rate of the SpB in Injun III which can reasonably be adopted as normalized to the SpB rates of Injun I.

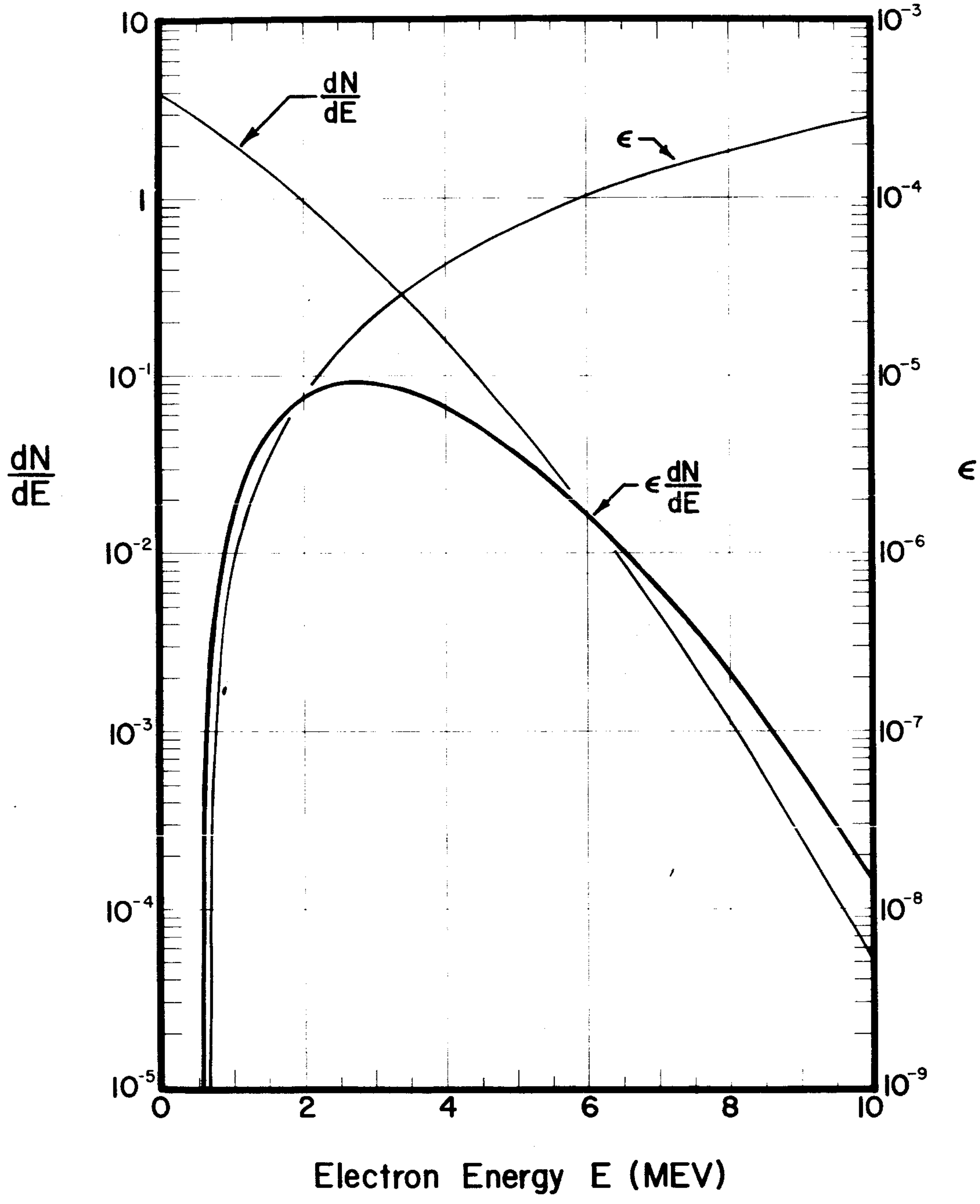
Figure 9. Reduced data on directly measured electron intensities of E $\gtrsim$ 250 keV in the outer zone ($\lambda \leq 30°$) in the region of the 22 October and 28 October 1962 Soviet artificial belts. Data from S.U.I. equipment in Explorer XIV (courtesy L. A. Frank).

Figure 10. Extension of Figure 9.

Figure 11. An example of temporal fluctuations of the intensity of electrons of energy E > 2 MeV in the natural outer zone at altitude of ~1000 km as measured with Explorer VII [Forbush, Venkatesan, and McIlwain, 1961].

Figure 12. Further examples of temporal fluctuations of the intensity of electrons of energy E > 2 MeV in the natural outer zone at altitudes of ~ 1000 km as measured with Explorer VII [Forbush, Pizzella, and Venkatesan, 1962].

Figure 13. A plot of the current solar activity cycle (Central Radio Propagation Laboratories, National Bureau of Standards, Boulder, Colorado).



10
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
0
2
4
6
8
10
$\frac{dN}{dE}$
ϵ
$\epsilon \frac{dN}{dE}$
Electron Energy E (MEV)

Figure 1

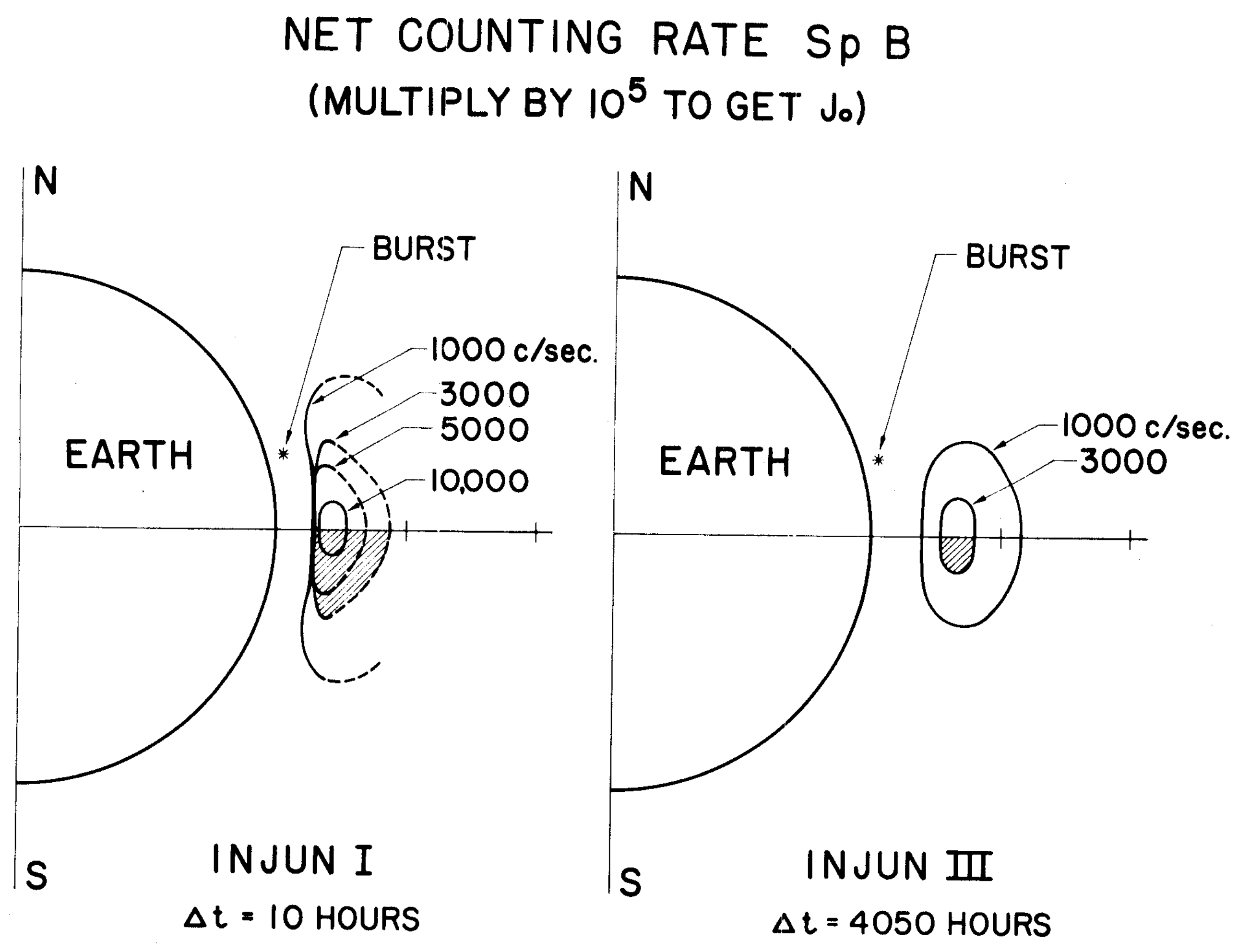
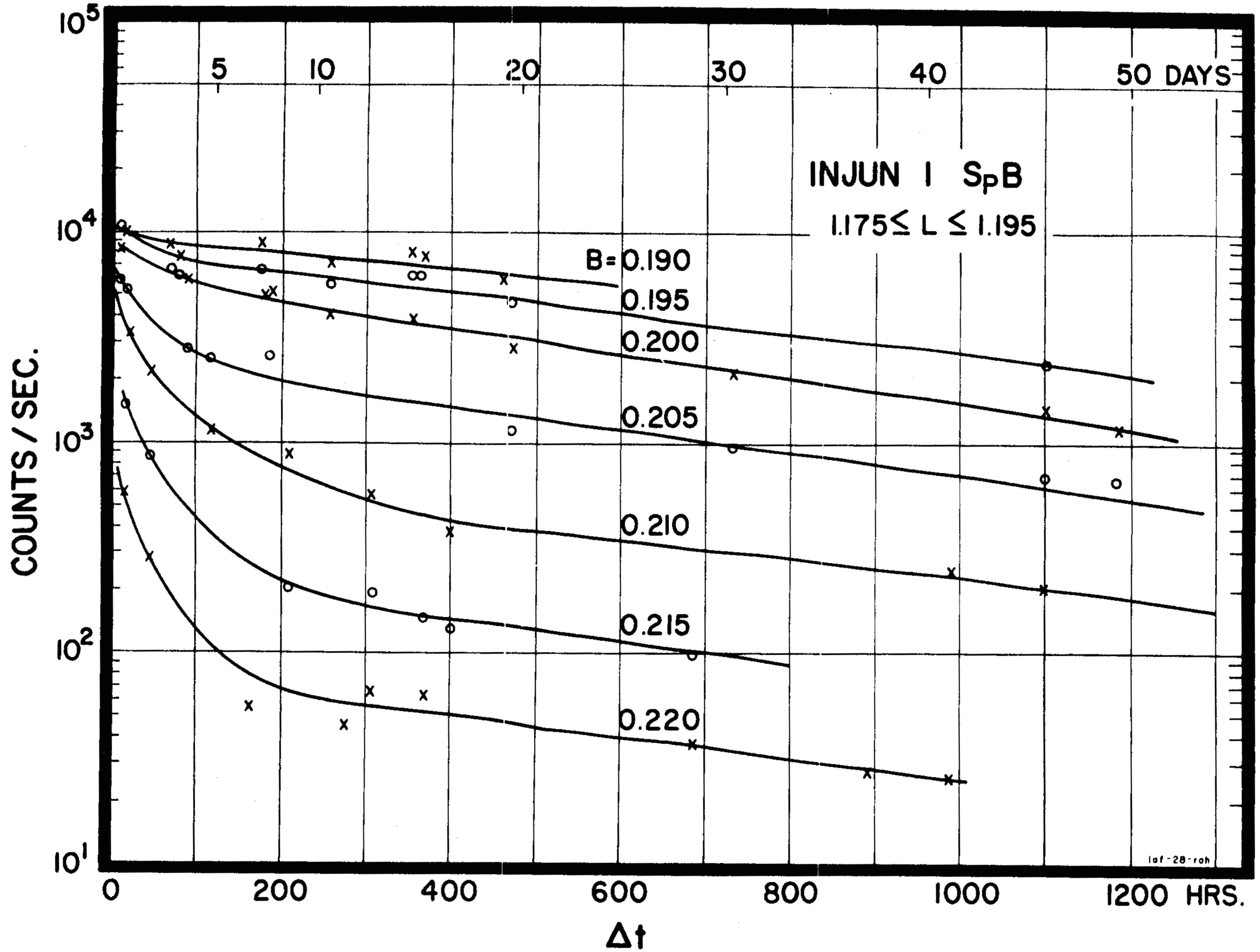
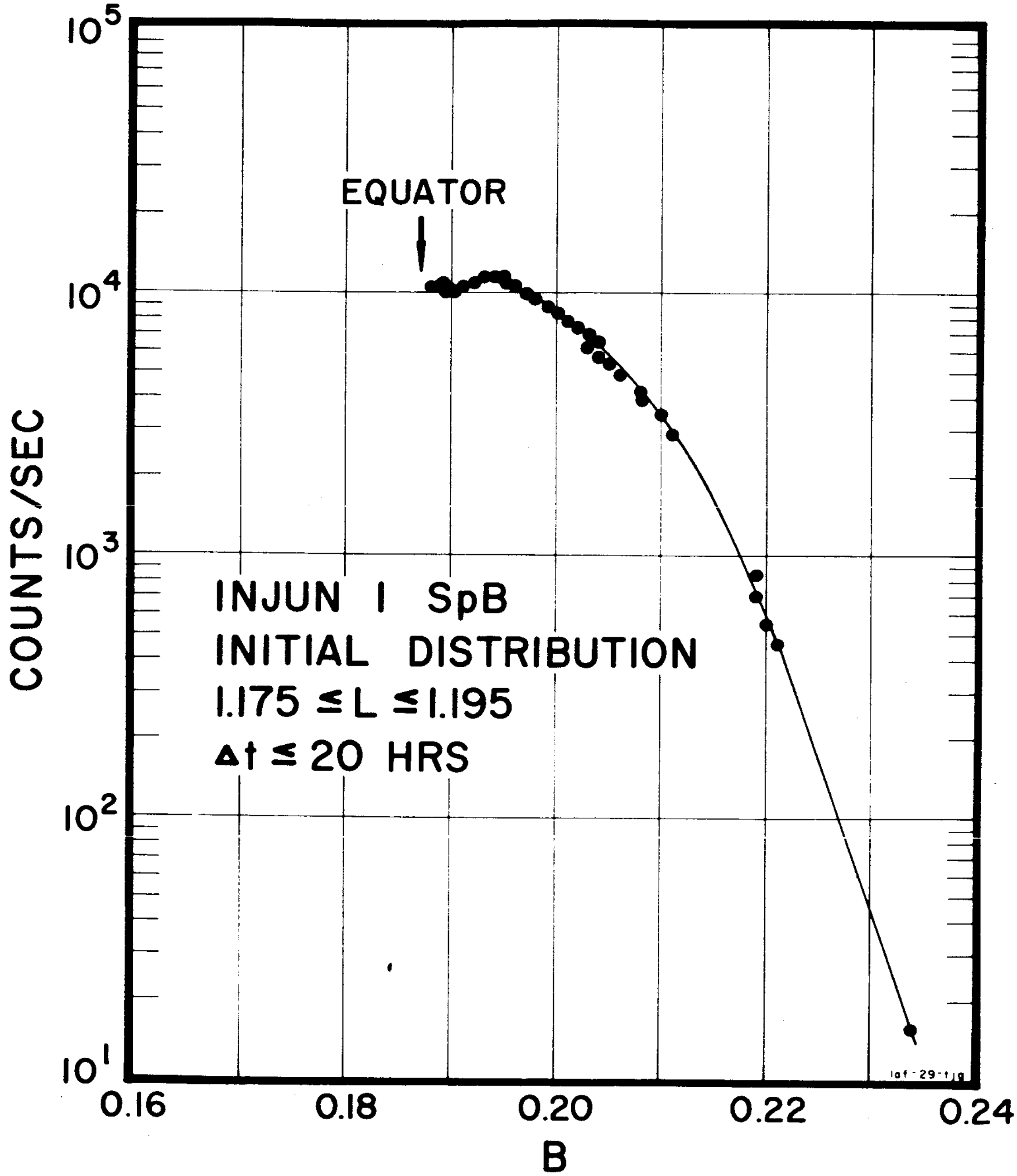

NET COUNTING RATE Sp B
(MULTIPLY BY 10^5 TO GET J$_0$)
N
S
EARTH
BURST
1000 c/sec.
3000
5000
10,000
INJUN I
Δt = 10 HOURS
N
S
EARTH
BURST
1000 c/sec.
3000
INJUN III
Δt = 4050 HOURS

Figure 2



INJUN I SpB
1.175≤ L ≤ 1.195
B=0.190
0.195
0.200
0.205
0.210
0.215
0.220
5
10
20
30
40
50 DAYS
COUNTS / SEC.
10^5
10^4
10^3
10^2
10^1
0
200
400
600
800
1000
1200 HRS.
Δt

Figure 3



EQUATOR
INJUN I SpB
INITIAL DISTRIBUTION
1.175 ≤ L ≤ 1.195
Δt ≤ 20 HRS
COUNTS/SEC
B
10^5
10^4
10^3
10^2
10^1
0.16
0.18
0.20
0.22
0.24

Figure 4

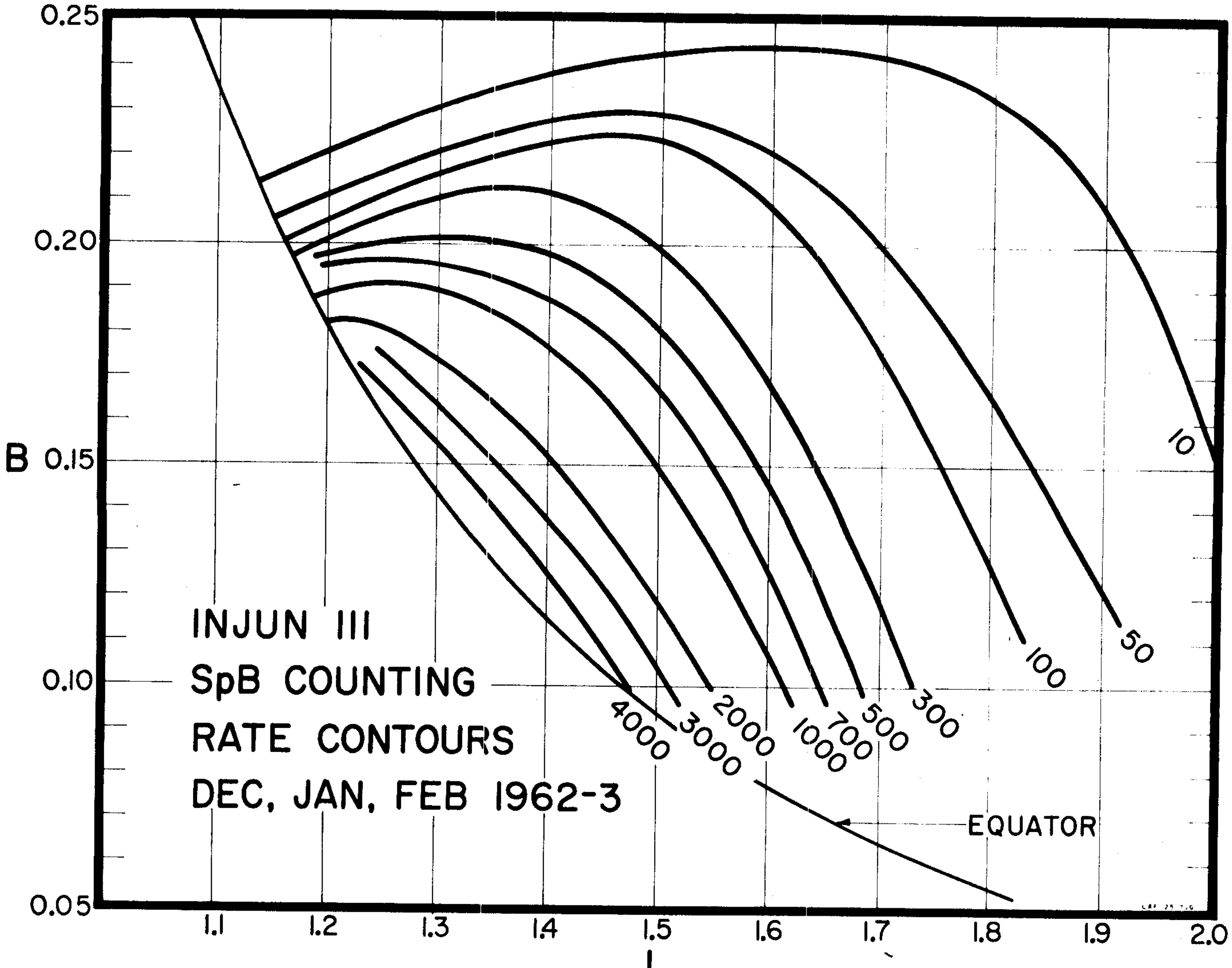

INJUN III
SpB COUNTING
RATE CONTOURS
DEC, JAN, FEB 1962-3
B
0.25
0.20
0.15
0.10
0.05
L
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.0
10
50
100
300
500
700
1000
2000
3000
4000
EQUATOR

Figure 5

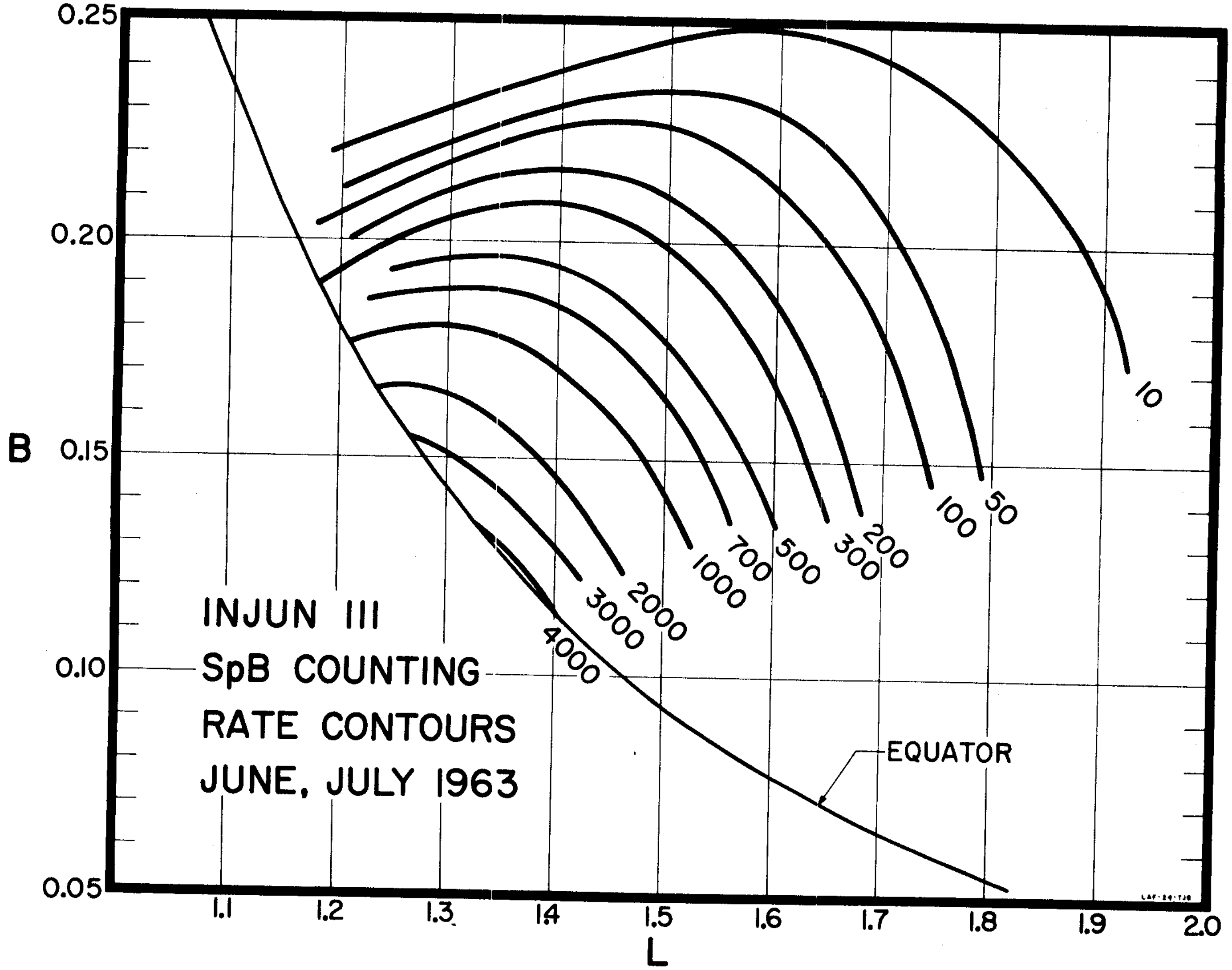

INJUN III
SpB COUNTING
RATE CONTOURS
JUNE, JULY 1963
EQUATOR
10
50
100
200
300
500
700
1000
2000
3000
4000
B
0.25
0.20
0.15
0.10
0.05
L
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.0

Figure 6

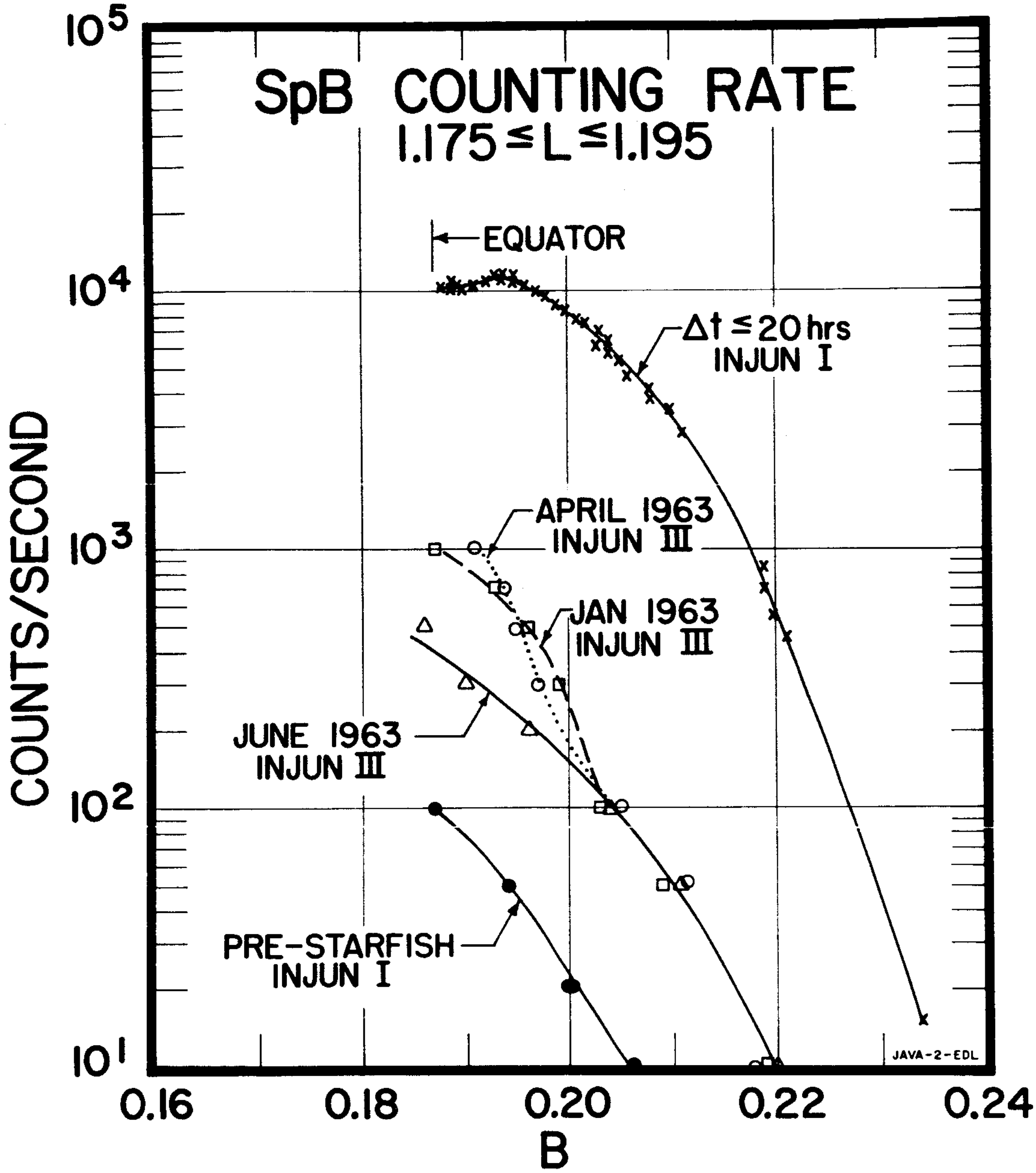

SpB COUNTING RATE
1.175 ≤ L ≤ 1.195
EQUATOR
Δt ≤ 20 hrs
INJUN I
APRIL 1963
INJUN III
JAN 1963
INJUN III
JUNE 1963
INJUN III
PRE-STARFISH
INJUN I
JAVA-2-EDL
COUNTS/SECOND
10⁵
10⁴
10³
10²
10¹
0.16
0.18
0.20
0.22
0.24
B

Figure 7

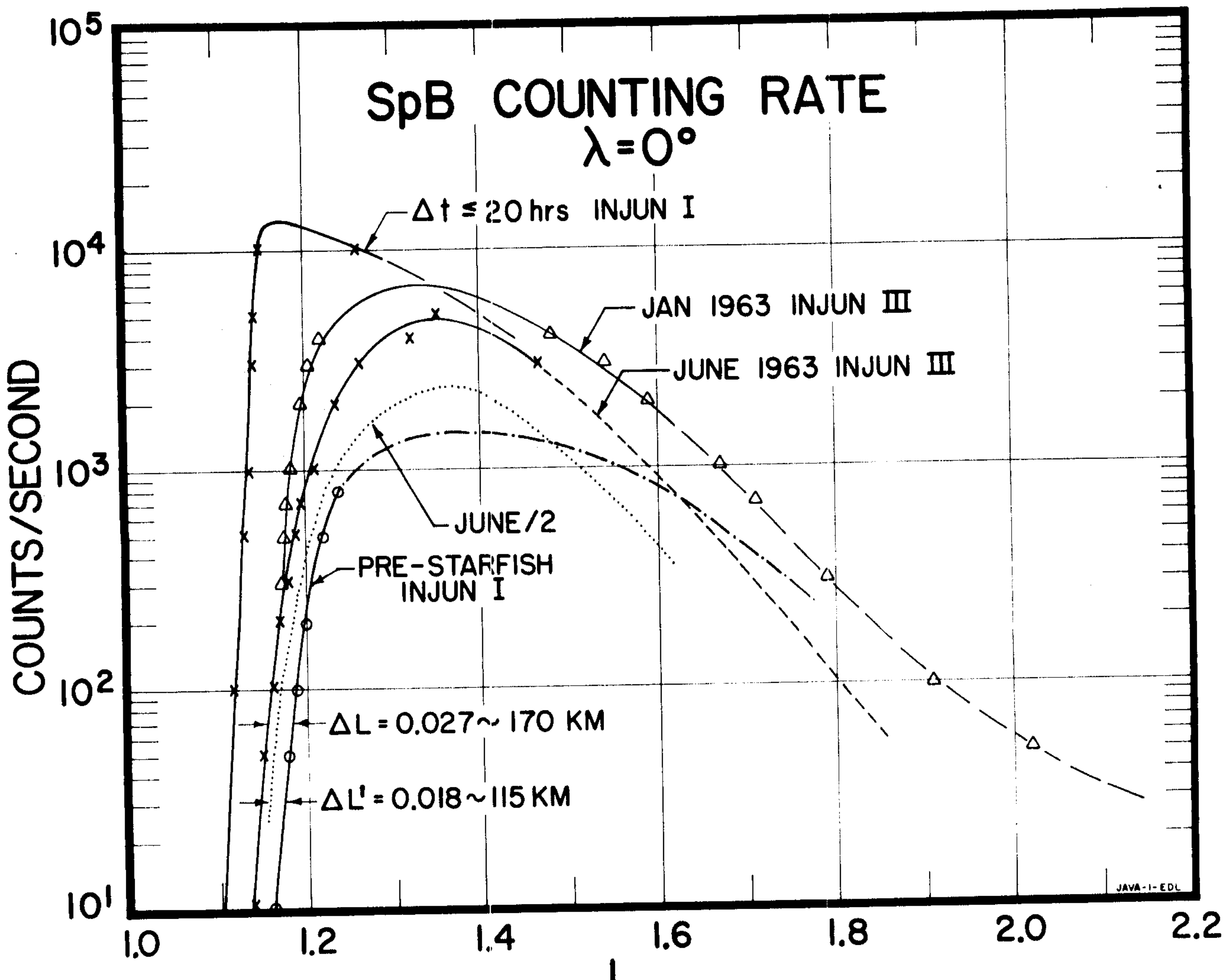

SpB COUNTING RATE
λ=0°
Δt ≤ 20 hrs INJUN I
JAN 1963 INJUN III
JUNE 1963 INJUN III
JUNE/2
PRE-STARFISH
INJUN I
ΔL = 0.027~ 170 KM
ΔL' = 0.018~115 KM
COUNTS/SECOND
10^5
10^4
10^3
10^2
10^1
1.0
1.2
1.4
1.6
1.8
2.0
2.2
L
JAVA-1-EDL

Figure 8

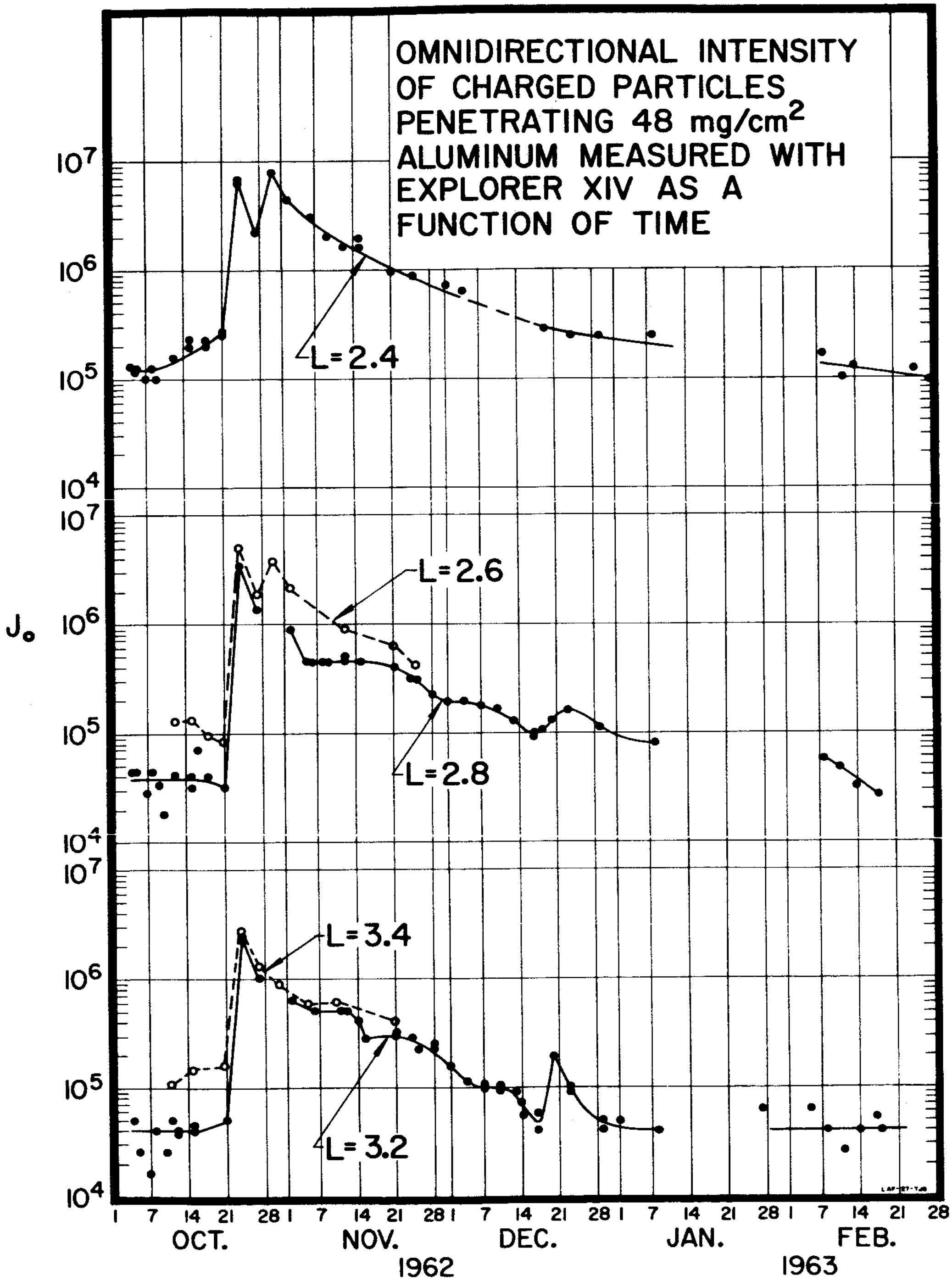

OMNIDIRECTIONAL INTENSITY OF CHARGED PARTICLES PENETRATING 48 mg/cm2 ALUMINUM MEASURED WITH EXPLORER XIV AS A FUNCTION OF TIME
L=2.4
L=2.6
L=2.8
L=3.4
L=3.2
J0
10^7
10^6
10^5
10^4
OCT.
NOV.
DEC.
JAN.
FEB.
1962
1963

Figure 9

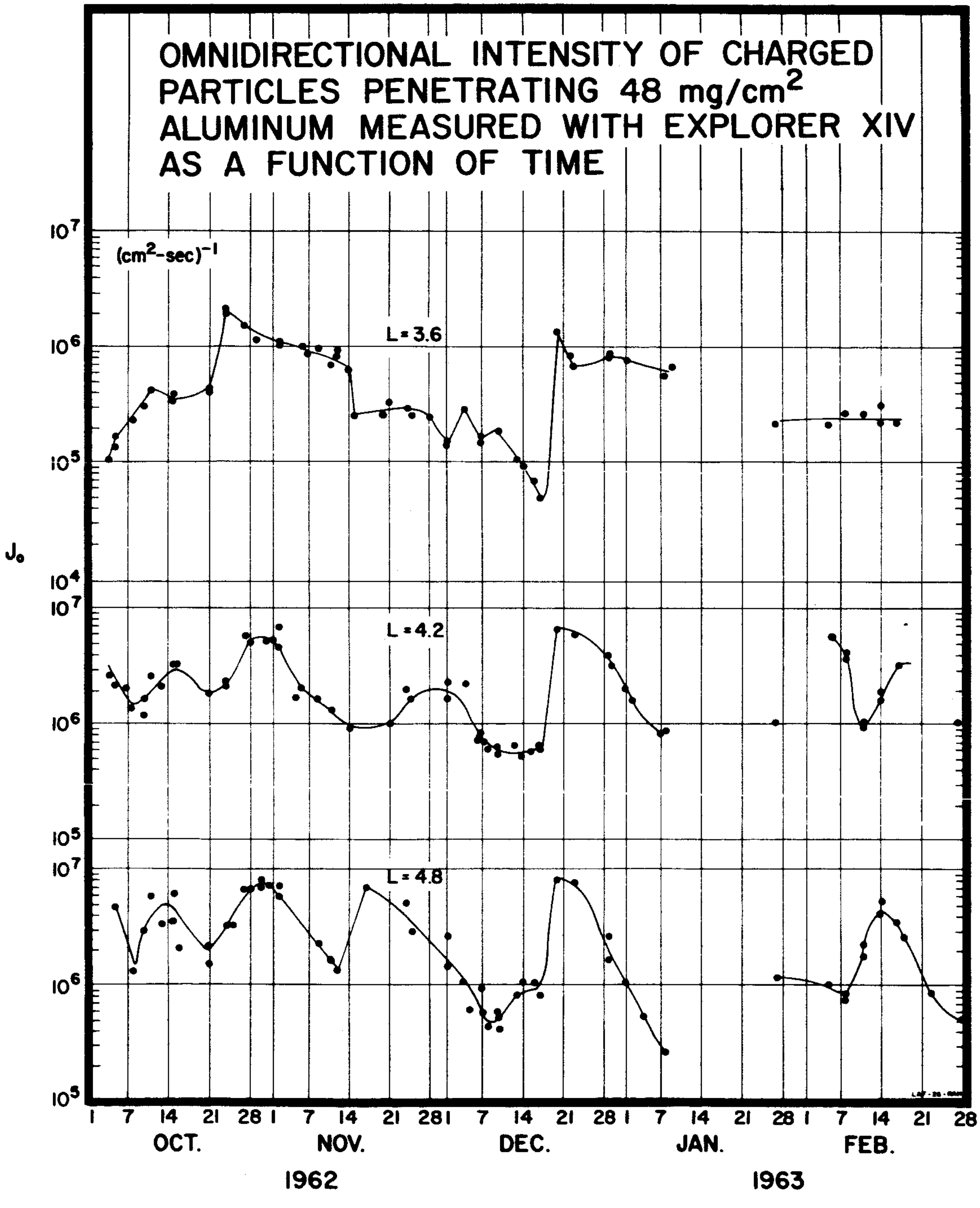
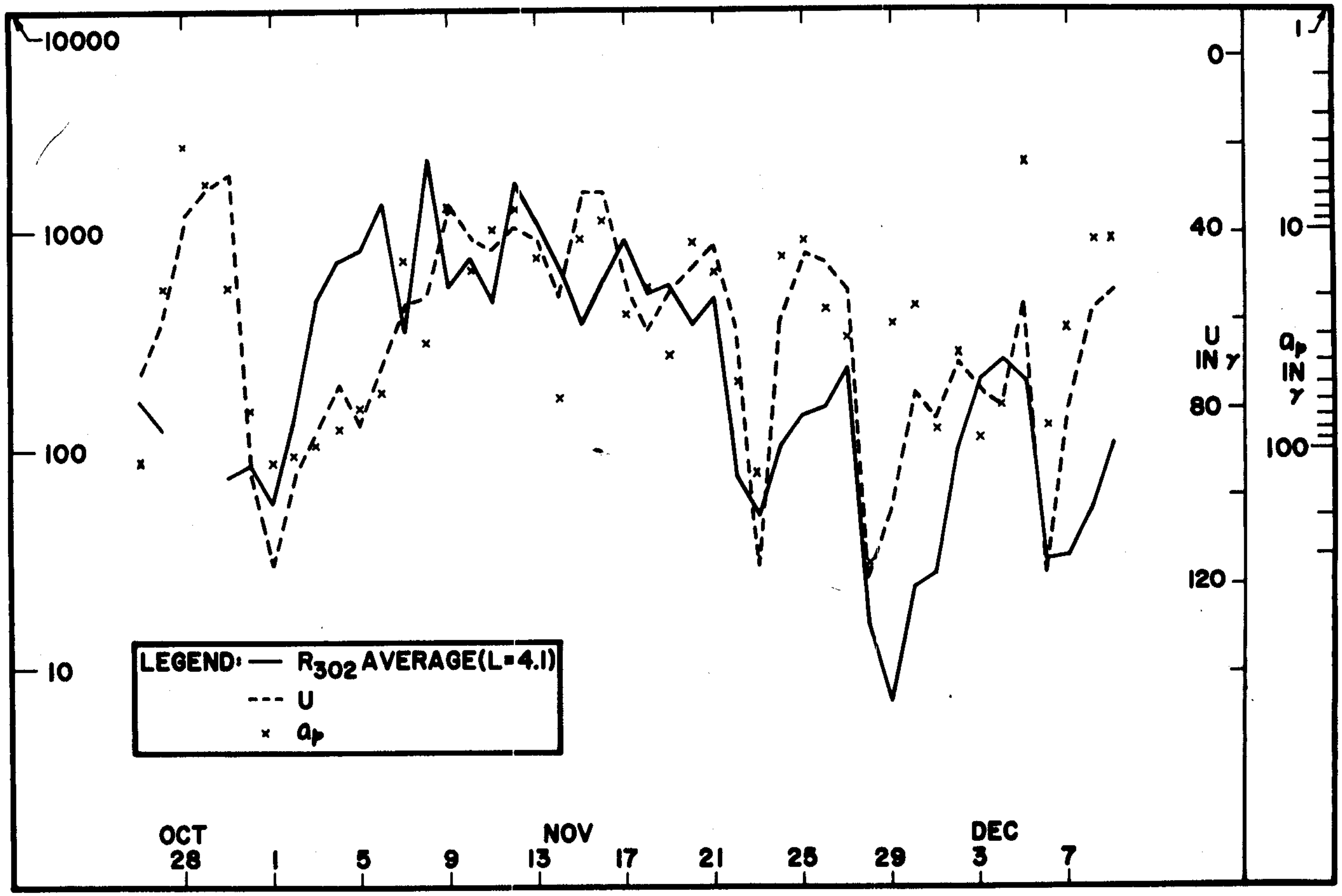
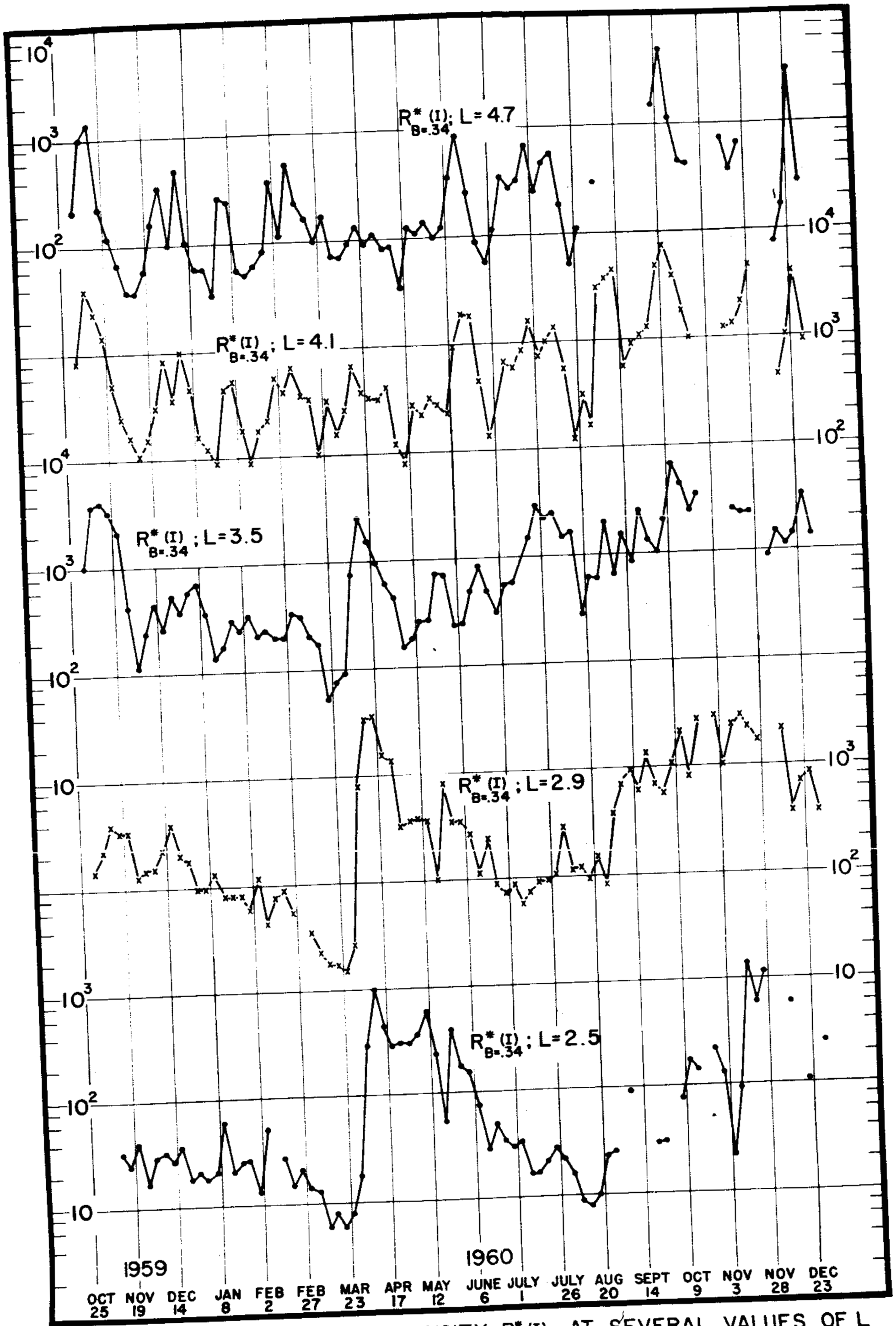

OMNIDIRECTIONAL INTENSITY OF CHARGED PARTICLES PENETRATING 48 mg/cm²
ALUMINUM MEASURED WITH EXPLORER XIV
AS A FUNCTION OF TIME
(cm²-sec)⁻¹
J₀
L = 3.6
L = 4.2
L = 4.8
10⁷
10⁶
10⁵
10⁴
1 7 14 21 28 1 7 14 21 28 1 7 14 21 28 1 7 14 21 28 1 7 14 21 28
OCT.
NOV.
DEC.
JAN.
FEB.
1962
1963

Figure 10



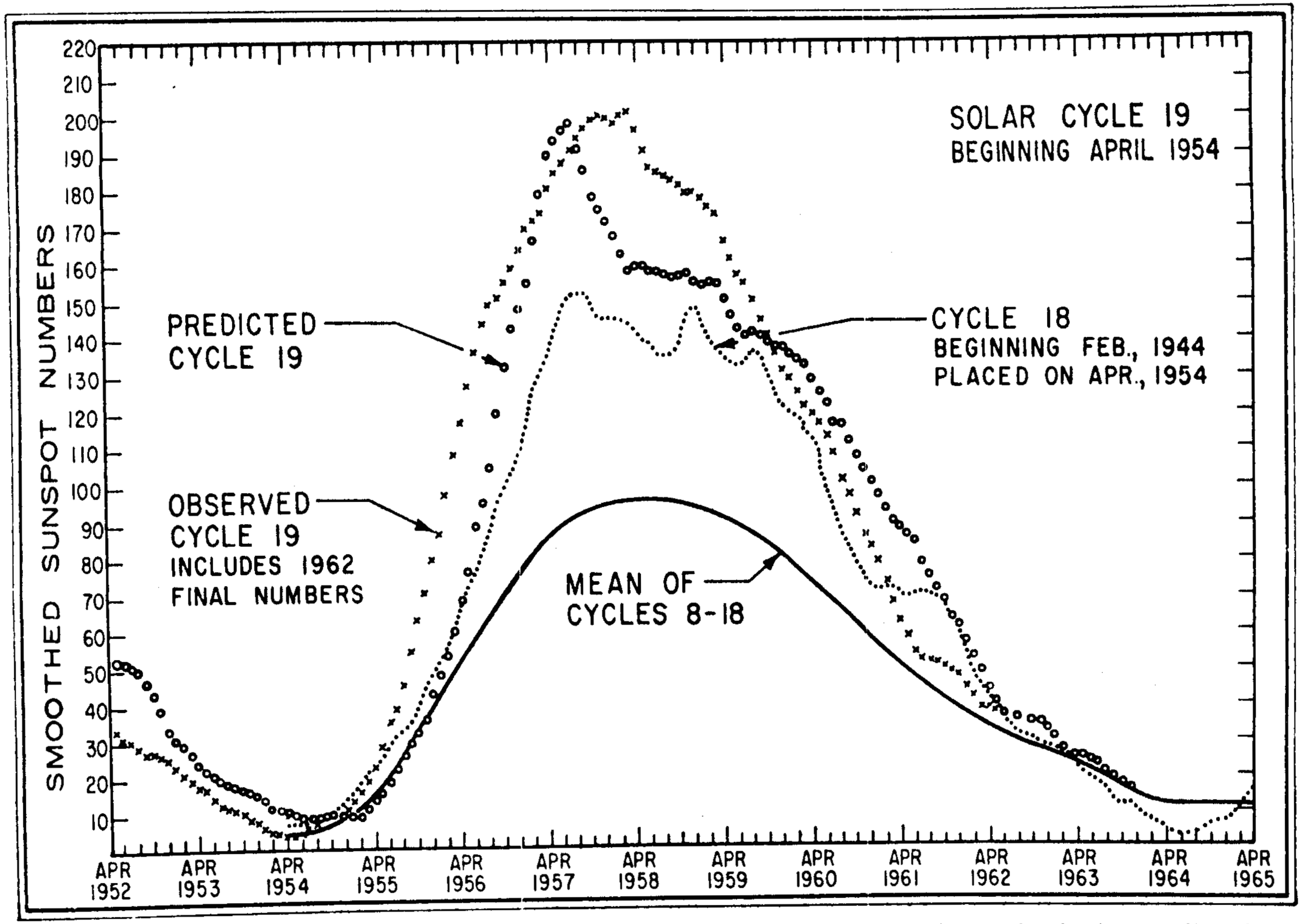
AVERAGE COUNTING RATE, R_{302} AT L=4.1 FROM PASSES FOR EACH "DAY", EQUATORIAL RING CURRENT MEASURE U, AND MAGNETIC ACTIVITY a_p, OCT. 26—DEC. 9, 1959

Figure 11



FIVE DAY AVERAGES OF INTENSITY $R^*_{B=.34}(I)$ AT SEVERAL VALUES OF L

Figure 12



Sunspot Numbers for the Current Solar Activity Cycle—Cycle 19. Both the predicted and actually observed numbers of sunspots for Cycle 19 are shown; also shown, for comparison, are Cycle 18 and the mean of Cycles 8-18. (Based on graph by the Central Radio Propagation Laboratories, NBS, Boulder, Colorado.)

Figure 13